

EVALUATION OF RATIONAL METHOD “C” VALUES

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OBJECTIVES

There are six objectives for this study.

1. Review the runoff factors “C” values for the Rational procedure specified in the current Design and Procedure Manual.
2. Review other references.
3. Review the more detailed land use elements that are identified in the County general Plan and estimate the percent of area that is impervious associated with each.
4. Develop an expanded table of “C” values that are consistent with the existing values, but provide a greater range of categories that relate to General Plan Land Use categories. Also, provide a mathematical relationship between land use, soil type that can be used more easily for computation and programming purposes.
5. Provide a table on “CN” values for the County Land Use categories that are consistent with the County Hydrology Manual.
6. Provide a method of determining “C” or “CN” values for special situations.

I. COUNTY OF SAN DIEGO HYDROLOGY MANUAL

Table I shows the Runoff Coefficient values in the current Design and Procedure Manual.

Table I

Land Use	Soil Group			
	A	B	C	D
Single Family	0.40	0.45	0.50	0.55
Multi-Units	0.45	0.50	0.60	0.70
Mobile Home	0.45	0.50	0.55	0.65
Rural (lots greater than ½ acre)	0.30	0.35	0.40	0.45
Commercial (80% Impervious)	0.70	0.75	0.80	0.85
Industrial (90% Impervious)	0.80	0.85	0.90	0.95

II. REVIEW OF “C” VALUES

Numerous references that use the “Rational” procedure were reviewed and the “C” values and procedures of determining the runoff were evaluated. Examples include the procedures used by Riverside County, Los Angeles County, Orange County, City of San Francisco, City of Oakland, Denver Urban Drainage District, and references from APWA and ASCE. County Flood Control has evaluated precipitation and stream flow recorded data since the Flood Control District was established in 1968. Extensive analysis of the methodology for the rational and unit hydrograph procedures has also been accomplished. This includes analysis of the runoff process and comparison of the two methods. This experience provides a basis for the development of this report.

In 1969, Design and Construction of Sanitary and Storm Sewers and the 1992 Design and Construction of Urban Storm water Management Systems were published by the American Society of Civil Engineers and the Water Environmental Federation. This Manual gives a range of runoff coefficients values for different land uses and types of ground surfaces as shown in Table II

Table II

Land Use/Type of Surface	Range of “C” Values
Business downtown	0.70 to 0.95
Business in neighborhoods	0.50 to 0.70
Single family	0.30 to 0.50
Multi-units, detached	0.40 to 0.60
Multi-units, attached	0.60 to 0.75
Suburban Residential	0.25 to 0.40
Apartment	0.50 to 0.70
Light Industrial	0.50 to 0.80
Heavy Industrial	0.60 to 0.90
Parks and Cemeteries	0.10 to 0.25
Playgrounds	0.20 to 0.35
Railroad yard	0.20 to 0.35
Unimproved land	0.10 to 0.30
Asphalt and Concrete	0.70 to 0.95
Brick	0.70 to 0.85
Roofs	0.75 to 0.95
Sandy soil lawn, 2 percent slope	0.05 to 0.10
Sandy soil lawn, 2 to 7 percent slope	0.10 to 0.15
Sandy soil lawn, >7 percent slope	0.15 to 0.20
Heavy soil lawn, 2 percent slope	0.13 to 0.17
Heavy soil lawn, 2 to 7 percent slope	0.18 to 0.22
Heavy soil lawn, >7 percent slope	0.25 to 0.35

III. SAN DIEGO COUNTY LAND USE ELEMENTS

There are 28 different types Land Use Elements within the County of San Diego General Plan. Of the 28 Land Uses, 15 have densities of one or more dwelling units per acre and are listed in Table III with respect to their Land Use Element Number. The effective percent impervious is based on discussions with the Planning Department, evaluation of typical land use patterns, amount of roofs, driveways, parking surfaces, etc. that are direct/indirect connection to the storm system and the Soil Conservation Service (SCS) criteria in the County Hydrology Manual.

Table III

Land Use Criteria		Land Use Element Number	(%) Imper.
SCS Elements	County Elements**		
Low	Residential, 1.0 DU/A*	2	10
Low	Residential, 2.0 DU/A*	3	20
Low	Residential, 2.9 DU/A*	4	25
Medium Density	Residential, 4.3 DU/A*	5	30
Medium Density	Residential 7.3 DU/A*	6	40
Medium Density	Residential, 10.9 DU/A*	7	45
Medium Density	Residential, 14.5 DU/A*	8	50
High Density	Residential, 43.0 DU/A*	9	80
High Density	Residential, 24.0 DU/A*	10	65
Commercial/Industrial	Office Professional/Commercial	11	90
Commercial/Industrial	Neighborhood Commercial	12	80
Commercial/Industrial	General Commercial	13	85
Commercial/Industrial	Service Commercial	14	90
Commercial/Industrial	Limited Industrial	15	90
Commercial/Industrial	General Industrial	16	95

* Dwelling Units/Acre

** Land Use Element numbers 2 through 6 typically represent single-family, and Land Use Element numbers 7 through 10 typically represent townhouse, condominium, and apartment categories. Mobil Home Parks contain various amounts of pervious areas. The County General Plan assigns the Mobil Home category to many Land Use Elements. In the unincorporated area, Land Use Element 8 probably best represents the typical Mobil Home Park.

IV. EVALUATION OF THE RUNOFF COEFFICIENT EQUATION AND VALUES

Some of the rain that falls on pervious surfaces infiltrates into the soil and the remainder runs off. Most of the rain that falls on impervious surfaces runs off. For this study, 90 percent of the rain on impervious surfaces runs off. The 90 percent value is based on a review of literature, and is considered reasonable since most impervious surfaces, such as parking lots, streets, etc., have some pervious areas and water can infiltrate through cracks and other openings. There is storage of water on the surface in depressions and in the form of surface flow depth and storage in conveyance systems. See page 3-5 of Los Angeles County Manual.*

The percent of rain that runs off from the pervious surfaces is the function of soil type A, B, C, and D. Runoff coefficients for “Rural (lots greater than ½ acre)” land use are shown in Table I. These values include a percentage of imperviousness. Table II shows a “C” value range of 0.18 to 0.22 for heavy soil lawns at 2 to 7 percent slopes. These values are much lower than the “Rural” coefficients in Table I. A reduction of 0.10 from the “Rural” coefficients is used to represent a more realistic value of runoff coefficients for pervious surfaces. These values are represented in Table IV as the pervious coefficient runoff value (C_p). Even with this reduction, these values are higher than the lawn coefficients in Table II. Most single-family residential units have lawns and/or landscaped areas that are more previous than most natural soils and vegetation cover in the San Diego coastal and foothill area.

Table IV
PERVIOUS COEFFICIENT RUNOFF VALUE (C_p)

Soil Type			
A	B	C	D
0.20	0.25	0.30	0.35

The Los Angeles County Manual* provides the following relationship:

$$C = 0.90 (\% \text{ impervious}) + C_p (\% \text{ pervious})$$

* Department of Public Works Hydrology Manual, December 1991 edition.

Where the runoff coefficient is the percent that runs off from the impervious area plus the percent that runs off from the pervious area. The percent that runs off from an impervious area is 90 percent of the percent impervious, and the percent that runs off from a pervious area is C_p times the percent pervious.

Using the relationship from the Los Angeles Manual, the percent pervious is 100 percent minus percent impervious value. The equation above can be rewritten as follows:

$$C = 0.90 (\% \text{ impervious}) + C_p (1 - \% \text{ impervious}) \quad (\text{Eq. 1})$$

“C” values determined from equation 1 for County Land Uses and soil types are shown in Table V.

Table V
ADJUSTED RUNOFF COEFFICIENT “C”

Land Use	(% Imper.	Soil Type (C _p)			
		A (0.20)	B (0.25)	C (0.30)	D (0.35)
2	10	0.27	0.32	0.36	0.41
3	20	0.34	0.38	0.42	0.46
4	25	0.38	0.41	0.45	0.49
5	30	0.41	0.45	0.48	0.52
6	40	0.48	0.51	0.54	0.57
7	45	0.52	0.54	0.57	0.60
8	50	0.55	0.58	0.60	0.63
9	80	0.76	0.77	0.78	0.79
10	65	0.66	0.67	0.69	0.71
11	90	0.83	0.84	0.84	0.85
12	80	0.76	0.77	0.78	0.79
13	85	0.80	0.80	0.81	0.82
14	90	0.83	0.84	0.84	0.85
15	90	0.83	0.84	0.84	0.85
16	95	0.87	0.87	0.87	0.87

The adjusted “C” values shown in Table V provide a much more comprehensive basis for basin analysis that is consistent with the County General Plan. To provide a comparison with the “C” values that are in the Design and Procedure Manual (1968) that was approved in 1968 and has been used since then, Table V-A compares the current values “Manual (1968)” with the “Adjusted” values.

The Land Use categories in the County General Plan that most closely represent the Manual “1968” Land Use classifications are compared in Table V-A. The largest discrepancies are for Soil Type A, Mobile Home and Multi-Units, which are different by 22 and 47 percent, respectively. Similarly, B soils have 16 and 34 percent increases. Since the amount of A soil in the San Diego coastal/foothill areas are relatively small, the percent differences would not significantly affect the computed flood flows in most basins. The adjusted values are more representative of actual runoff since the impervious area factor is included more effectively than in the 1968 Manual.

**Table V-A
COMPARISON OF “C” VALUES**

Manual vs. Adjusted	Land Use	Soil Type			
		A	B	C	D
Manual (1968)	Rural	0.30	0.35	0.40	0.45
Adjusted	L. U. #2	0.27	0.33	0.36	0.41
Different (%)		-10	-6	-10	-9
Manual (1968)	Single Family	0.40	0.45	0.50	0.55
Adjusted	L. U. #5	0.41	0.45	0.48	0.52
Different (%)		3	0	-4	-5
Manual (1968)	Mobil Homes	0.45	0.50	0.55	0.65
Adjusted	L. U. #8	0.55	0.58	0.60	0.63
Different (%)		22	16	9	-3
Manual (1968)	Multi-Units	0.45	0.50	0.60	0.70
Adjusted	L. U. #10	0.66	0.67	0.69	0.71
Different (%)		47	34	15	1
Manual (1968)	Commercial (80%)	0.70	0.75	0.80	0.85
Adjusted	L. U. #12	0.76	0.77	0.78	0.79
Different (%)		9	3	-3	-7
Manual (1968)	Industrial (90%)	0.80	0.85	0.90	0.95
Adjusted	L. U. #14 or #15	0.83	0.84	0.84	0.85
Different (%)		4	-1	-7	-11

To obtain “C” values directly from Table I for categories that correspond to County Land Use Elements (Table III), it is necessary to develop a matrix similar to Table V. Individuals independently developing this matrix would have significantly different “C” values because of the way they interpret the criteria in Table I. Table V provides a rational and more consistent basis for “C” values.

V. RUNOFF CURVE NUMBERS (CN) FOR THE SOIL CONSERVATION SERVICE HYDROLOGY METHOD

Table VI contains values of CN from the County Hydrology Manual for Hydrologic Condition II. The numbers in bold are taken directly from the Manual and the others are interpolated.

**Table VI
CURVE NUMBERS**

Land Use	Land Use Element Number	Soil Type			
		A	B	C	D
	2	68	77	83	86
Low Density Residential	3	70	78	84	87
	4	71	79	85	87
Medium Density Residential	5	73	80	86	88
	6	73	80	86	89
	7	73	81	87	89
	8	74	81	87	89
	9	83	87	90	91
High Density Residential	10	75	82	88	90
	11	89	90	91	92
	12	86	88	90	92
	13	92	92	92	93
Commercial/Industrial	14	89	90	91	92
	15	92	92	92	93
	16	92	92	92	93

VI. SPECIAL EVALUATION OF “C” AND “CN” VALUES

Some basins have land use that is not consistent with the typical development associated with categories listed in Table III. As an example, some projects cluster units so that what would typically be high-density, single-family houses on individual lots, instead are constructed as two or three story condominiums. This provides much more open space than would be available with the typical land use and would allow infiltration into grass, vegetated or natural ground cover. A lower “C” value than the one listed in Table V for the Land Use would be used. If the development is not standard and it can be clearly demonstrated that the infiltration is greater than the “C” value for land use specified, a special comprehensive study may be developed to provide appropriate “C” or “CN” values. Equation 1 may be used as appropriate.

Values for the unit hydrograph procedure (CN Values) can be developed using Table VI in this Report and the soil/coverage descriptions given in the County Hydrology Manual.

VII. SUMMARY AND CONCLUSION

The “C” values tabulated in Tables V provide better consistency with the County Land Use Elements than the values in the 1968 Design and Procedure Manual. This relationship with the General Plan Land Use is desirable since it provides more consistency between drainage basin studies. The 1968 Manual “C” values (compared in Table V-A) are reasonably close to the Adjusted “C” values, except for the A and B soil type Mobil Home and Multi-Units categories. These categories are a relatively small portion of the County coast/foothill urban area and the adjusted “C” values better reflect expected runoff conditions.

Since the values in Table V and VI are consistent with County Land Use categories and reflect the existing County criteria identified in the 1968 Manual, they provide a good basis for storm water runoff analysis and watershed plans.